

GaN Thin Films Grown on Hydrogen Plasma Cleaned Sapphire Substrates by Plasma-Assisted MOCVD

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Abstract

Gallium Nitride (GaN) is one of the most promising wide-bandgap III-V semiconductor for optical devices operating in the blue to ultraviolet region and for high temperature and high power electronic devices. Technologically promising GaN films have been grown on sapphire substrates. In the present work, we report on the highly oriented GaN(0002) grown on hydrogen plasma cleaned (0001) sapphire substrates using plasma-assisted MOCVD. The low power downstream plasma cavity (ASTeX) was used to supply reactive nitrogen plasma from N_2 gas and reactive hydrogen plasma from H_2 gas. The N_2 plasma is generated by 2.45 GHz microwave of 250 watts and uncracked trimethylgallium (TMGa) was used as Ga source. GaN thin films were grown at temperature of 640 °C with TMGa flow rates of 0.8 sccm and N_2 flow rates of 90 - 130 sccm for 2 hours. Typical growth rate of GaN films was about 200 nm/h. The H_2 flux was varied from 0 to 50 sccm in order to investigate the effect of the reactive hydrogen plasma for thermal cleaning process of the substrate. The thermal cleaning of substrates was carried out at temperature of 650 °C for 10 minutes. The GaN thin films were characterized by XRD, Hall measurement and UV-Vis spectrometry. XRD investigation revealed that the GaN film grown on sapphire substrate without hydrogen plasma as thermal cleaning have a mixture of crystallites oriented along $(10\bar{1}0)$, (0002) and $(10\bar{1}1)$. As the substrates was cleaned by hydrogen plasma, the relative intensity of GaN(0002) to GaN($10\bar{1}0$) and GaN($10\bar{1}1$) are increased as H_2 flux increased. The GaN film with (0002) orientation at the H_2 flux of 50 sccm and N_2 flow rate of 130 sccm have a FWHM of 0.30 deg. The GaN film grown on hydrogen plasma cleaned sapphire substrates tend to have a single crystal orientation of (0002). Hall measurement at room temperature showed the increase of Hall mobility of 16 cm²/V·s to 162 cm²/V·s with increasing H_2 flux. The improvement of electrical properties shows that the substrate contamination decreased by hydrogen plasma cleaning. Optical absorption spectra shows that the optical properties of GaN films grown on hydrogen plasma cleaned sapphire substrates is also better. At H_2 flux of 40 sccm, the GaN film has a bandgap energy of 3.40 eV.

Table 1: Parameters of deposition

Sample	H ₂ flow rates for thermal cleaning (sccm)	TMGa flow rates (sccm)	N ₂ flow rates (sccm)	Growth temperature (°C)
(#a)	0	0,8	90	640
(#b)	25	0,8	90	640
(#c)	40	0,8	90	640
(#d)	50	0,8	130	640

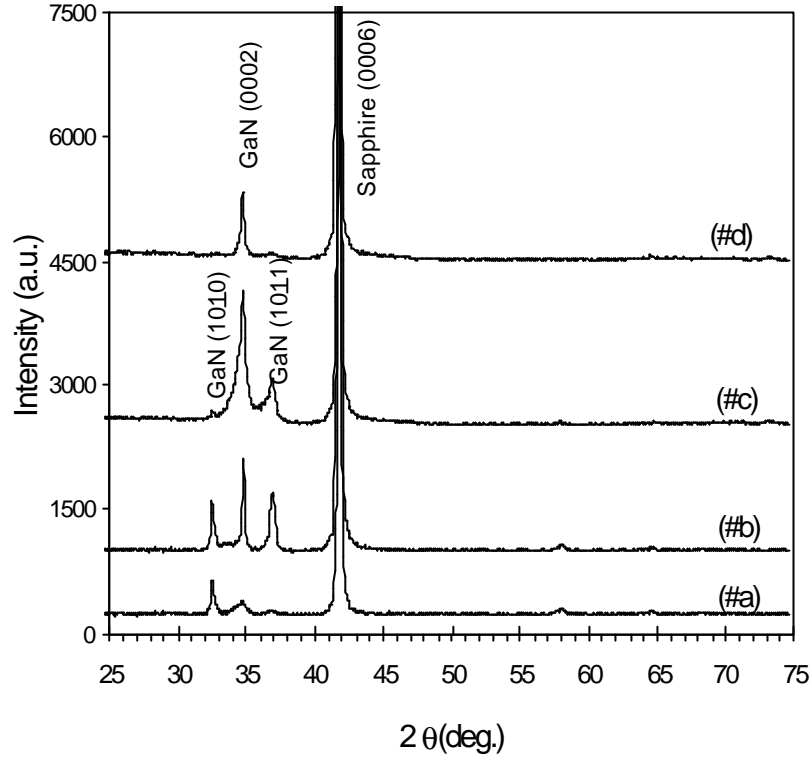


Figure 1. XRD of GaN films grown on hydrogen plasma cleaned sapphire substrate. The relative intensity of GaN(0002) to GaN($10\bar{1}0$) and GaN($10\bar{1}1$) are increased as H₂ flux increased.

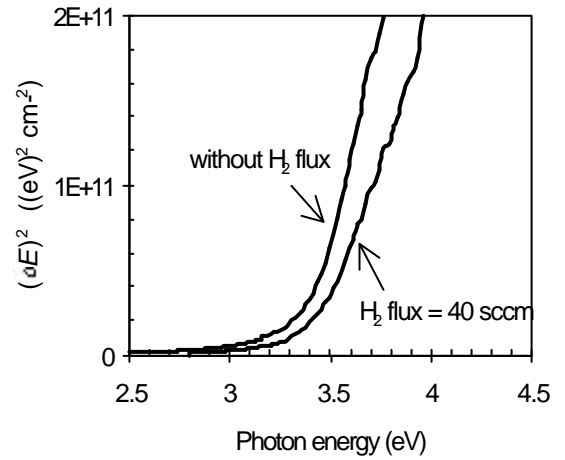
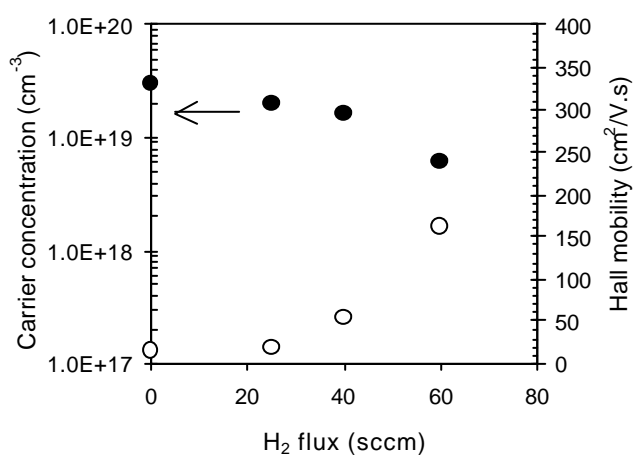


Figure 2. Electrical properties of GaN films grown on hydrogen plasma cleaned sapphire substrates as a function of H_2 flux.

Figure 3. Optical absorption spectra of GaN film on sapphire substrate without H_2 plasma cleaning and with plasma cleaning using 40 sccm H_2 flux

